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COMPARATIVE EVALUATION OF THE BACHARACH "TLV SNIFFER" AND THE HEATH "DETECTO-PAK II" FOR MONITORING AT THE MIDWAY LANDFILL

WASHINGTON STATE DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE CLEANUP PROGRAM

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Comparative Evaluation of the Bacharach "TLV Sniffer" and the Heath "Detecto-Pak II" for Monitoring at the Midway Landfill

This report presents the results of the Washington State Department of Ecology's comparative evaluation of two types of combustible gas indicators - the Bacharach "TLV Sniffer"* and the Heath "Detecto-Pak II."* This evaluation was conducted at the request of the Seattle-King County Health Department. Because of the considerable public interest in this comparison, time was a major constraint and a rigorous analytical test program was not conducted. The parameters addressed in this evaluation were those deemed most likely to affect instrument performance in the vicinity of the Midway Landfill. Other parameters not evaluated in this work could affect instrument performance, particularly in other applications. Also, other instruments of the same brand may respond differently from those tested. The reader is cautioned not to use the results of this evaluation without careful consideration of these limitations.

SUMMARY

In 1985 studies by the City of Seattle and Ecology found extensive migration of methane gas originating from the Midway Landfill. Since late summer 1985, numerous homes and businesses have been checked for the presence of landfill gas using an instrument called the "TLV Sniffer" (TLV). This instrument represented a major improvement over earlier meters used at Midway. The TLV has proved very valuable by detecting gas in several buildings so that the occupants could be evacuated or other protective measures taken before the gas reached an explosive concentration.

During late 1985 and 1986 numerous steps were taken by Ecology and the City of Seattle to attempt to control this off-site gas migration. While the gas migration problem has not been totally solved, these efforts have reduced gas concentrations in many off-site areas. Buildings where elevated gas concentrations had been found earlier have shown greatly reduced TLV readings in the last several months. Recently, many of these buildings were rechecked by Heath Consultants using a different meter(Detecto-Pak II) and found to have no measurable combustible gas. These new findings and similar findings at another landfill prompted Seattle-King County Health Department to request that the Department of Ecology do comparison testing of the TLV Sniffer and Detecto-Pak II. The testing was done at the Weyerhaeuser Technology Center Laboratory using specially prepared gas samples, a gas sample from an extraction well and gas samples from select monitoring probes at Midway. It is

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*"TLV Sniffer" and Detecto-Pak II are registered trademarks of the Bacharach Corporation and Heath Consultants, Inc., respectively.

important to recognize that the readings in question are only those which are extremely low and far below the lower explosive limit* for methane. They do not impact decisions made to evacuate homes or other protective measures taken nor the extent of gas migration which has been reported in the vicinity of Midway.

CONCLUSIONS

Based on this testing, the following conclusions can be made:

1. Both the TLV Sniffer and Detecto Pak II (DP II) effectively detected low concentrations of methane under normal atmospheric conditions. While these low concentrations were detectable, both meters exhibited a considerable difference between the concentrations they measured and the laboratory measured concentrations, although the DP II faired somewhat better than the TLV in this regard. This indicates that while both of these meters are excellent scanning instruments, if precise measurements are desired, the readings obtained with the meters should be confirmed by laboratory analysis.

2. Neither meter is specific to methane but will detect other types of combustible vapors, such as jet fuel, gasoline or solvents.

3. Reduced oxygen concentrations as low as 15.5% did not affect either meter's ability to detect methane. At oxygen concentrations below 15.5% the DP II detector flame went out, making it ineffective for detecting methane in low oxygen conditions. The TLV did not exhibit this limitation. The inability of the DP II to operate at low oxygen conditions should not interfere with its ability to monitor homes but would require a modified sampling technique for probe monitoring.

4. Elevated concentrations of carbon dioxide caused a strong upscale response on the TLV's tested. No appreciable effect was observed on the DP II. Both meters can detect methane in elevated concentrations of carbon dioxide. The characteristic of the TLV to respond to elevated concentrations of carbon dioxide is not necessarily a disadvantage when scanning homes for the presence of landfill gas. This is because carbon dioxide, aside from methane, is the other major component of landfill gas. However, because elevated concentrations of carbon dioxide can naturally occur in soil, its presence does not necessarily mean landfill gas is present.

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*See footnote on page 6.

5. Both instruments were found to be affected by temperature changes. Transferring the TLV's from a cool to a warm environment resulted in an upscale drift. The opposite effect was experienced when transferring it from a warm to a cool environment. The DP II's experienced a similar but much lesser drift. This effect was a slow drift that a conscientious operator should notice and make appropriate adjustments for while using either meter.

6. Transferring the meters from a dry to moist atmosphere resulted in a strong upscale response by the TLV's tested. The DP-II's experienced only a minor response when subjected to these conditions. This indicates that when using the TLV, low concentration readings from moist sumps or drains should be viewed with caution, subject to further verification testing.

7. Both the TLV and DP II were able to detect methane when present in gas samples obtained from an extraction well and probes in the vicinity of Midway. The TLV's response to elevated carbon dioxide concentrations commonly resulted in it over estimating the combustible gas concentration.

8. The TLV was found to be affected more than the DP-II by handling, tipping and restricting of flow. The City's TLV "A" meter was much more sensitive to factors affecting its performance than Ecology's TLV "3". This is believed to be due to a faulty sensor or internal electrical problem with TLV A. This problem was evident from the meter instability on the 0-100 ppm scale. This sensitivity of the TLV emphasizes the need to maintain and use the meter properly to minimize meter drift. While the DP-II is less effected by these factors, proper maintenance and use of the instrument is essential to minimize meter drift with it as well.

RECOMMENDATIONS

Based on these conclusions, the following recommendations are made:

1. These results confirm that both the TLV and DP II can be used to scan for the presence of methane in buildings in the vicinity of Midway with confidence that levels presenting a safety hazard will be identified. In general, the TLV will tend to overestimate the amount of methane present, particularly at concentrations less than 100 ppm because of the many other factors that can also affect instrument performance. The DP II is less affected by these other factors. However, as with any field screening instrument, neither the TLV or DP II can be expected to provide absolutely precise concentrations. If precise concentrations are desired, it is recommended that samples be obtained for laboratory analysis using appropriate quality assurance/quality control procedures.

2. Given the new comparative information on the performance of these instruments it is recommended that the home monitoring criteria be

reexamined. Department of Ecology staff are available to provide technical assistance to help in this reevaluation.

3. When a TLV instrument is used for monitoring activities the following points need to be followed or taken into account:

   a. Proper maintenance of the TLV instrument is essential. This should include a check of all scales for stability. If an instrument is unstable on any scale, whether it is to be used on that scale or not - it should not be used for monitoring until the problem has been corrected.

   b. The instrument must be properly handled in use. This includes not tipping it or holding it next to the body where heat can cause meter drift. When monitoring point sources in a building, it is best to set the instrument down on a level surface.

   c. To obtain valid readings, gas flow into the instrument cannot be restricted. This includes keeping the instrument probe out of cracks or holes that could restrict instrument flow. Consideration should be given to equipping the TLV with a probe similar to that on the Heath DP II to minimize the opportunities for such restrictions to occur.

   d. Be aware that temperature, moisture and carbon dioxide cause meter drift. Any change in these factors needs to be considered when reporting readings.

   e. In general, a legitimate combustible gas reading can be recognized by a sharp upward movement of the needle on the meter. This response should be readily repeatable by different personnel using a different TLV. The time for the response will probably vary somewhat with each instrument depending on pump strength and other factors. This time can be best gauged by noting each meter's response time to a known source and using this as a guide when monitoring an unknown location. If the meter response is a slow upscale drift the reading should be considered suspect and all of the factors discussed above reviewed for possible influence before reporting this drift as an actual reading.

   f. Periodic quality control checks and refresher training of personnel using the instruments should be done to ensure the meters are being properly used.

4. If a different instrument other than the TLV is to be used in home monitoring such as the DP II, several steps should be taken to facilitate the transition:

   a. Any new instrument should be used in parallel with the TLV for several weeks. This should be done by the same personnel who will be using the new instrument so they can become familiar with its use. This will also provide comparative data for future analysis.

b. Several instruments or combination of instruments should be purchased to provide backup capability and allow for verification of readings by more than one instrument.

c. These instruments are more complex to maintain and use than the TLV. To ensure the instruments are being properly used, additional training and followup quality control checks will be needed. This includes checking to be sure the instruments are being used and maintained as per the manufacturers instructions.

d. Many of the factors discussed above for the TLV can also affect the performance of these other instruments, although to a much lesser degree. These instruments also have the limitation of flame-out in low oxygen conditions. These factors must be taken into account when using these instruments and reporting monitoring levels.

BACKGROUND

The Midway Landfill is a former municipal landfill located approximately 16 miles south of Seattle, in the City of Kent, Washington. It was operated by the City of Seattle Solid Waste Utility from 1966 to 1983. The landfilling occurred within the location of a former peat bog lake and gravel pit. The site is approximately 60 acres in size and contains an estimated 3 to 4 million cubic yards of municipal, commercial, and industrial wastes. Unknown quantities of hazardous wastes have been co-disposed with these wastes at the site. This, coupled with data indicating releases of hazardous substances to the environment had occurred, resulted in the site being nominated to and, in May 1986, formally added to the EPA's National Priorities List created under "Superfund."

As part of the preparation of a closure plan for the site by Seattle (independent of the Superfund designation), 15 gas probes were installed to depths varying up to 100 feet deep in the vicinity of the landfill. These probes, consisting of perforated plastic pipe placed in boreholes, were installed in spring and summer, 1985. Subsequent monitoring of these probes found combustible gas in them in excess of the lower explosive limit for methane*. These probes, many of which were located several hundred feet from the landfill and in areas of dense commercial and residential development, raised a concern that combustible methane could be entering these structures creating a potential safety hazard. Several buildings were checked by Seattle Engineering Department personnel using a Gas Tech combustible gas meter. This meter utilizes a hot filament detector and has a lower scale of 0 to 5 percent, making it most effective for measuring concentrations of 10,000 parts per million (ppm) or more. A sample is obtained by squeezing a bulb to hand pump the gas into the meter to obtain a reading. This monitoring found combustible gas present in two businesses adjacent to the landfill entrance.

Later, a more comprehensive neighborhood monitoring program was organized to check for the presence of combustible gas in the numerous homes and businesses located in the vicinity of the landfill. While suitable for monitoring the higher gas concentrations found in probes, the limited sensitivity of the Gas Tech meter and the difficulty of an individual to sustain the hand pumping action needed to use this meter for extended periods of time rendered it impractical for this monitoring. Instead, an instrument called the "TLV Sniffer" manufactured by the Bacharach Corporation was utilized. This meter was selected because several were available for immediate use and because Ecology, at another site, had found it to be extremely valuable for monitoring buildings for the presence of low amounts of combustible gas. This instrument operates on the same "hot filament" principle as the Gas Tech meter but has been designed with a much greater sensitivity to combustible gas. On its lowest scales this instrument can detect combustible gas at concentrations 10 to 100 times lower than the Gas Tech meter. It also is equipped with a built-in pump greatly facilitating its use when checking many buildings in a day.

These initial neighborhood "scans" with the TLV Sniffers were conducted in late summer and fall of 1985 by personnel from the Department of Ecology, the Kent Fire Department, the Seattle Engineering Department, and the Seattle-King County Health Department. During these scans numerous homes and businesses were identified where low readings were obtained.

It became evident to the personnel involved in these scans that several factors other than landfill gas could be causing the numerous low

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*The lower explosive limit is that concentration above which there is a sufficient concentration of methane to sustain combustion or burn and under the right conditions could result in an explosion. This concentration is generally accepted to be 5% or 50,000 parts per million, measured on a volumetric basis. This concentration can vary somewhat depending on the other gases present in the mixture.

readings measured, especially those less than 100 ppm. For this reason criteria were established to screen out what were thought to be "background" or normal instrument noise and to set priorities for future follow-up monitoring. These criteria, later set forth in a letter from the Seattle-King County Health Department to the City of Seattle, called for the following actions (in part[1]):

0-50 ppm	Consider ambient air, normal condition
50-100 ppm	Monitor as frequently as staff size permits
100 and up	Monitor daily
5000 ppm	in atmosphere evacuate building
10,000 ppm	in small confined space evacuate building
40,000 ppm	at point source evacuate building

These "action levels" were widely publicized, including listing for several weeks on the report of monitoring results issued to homeowners. Later, newsletters issued by the Department of Ecology and Seattle Engineering would offer further explanation of factors which can cause low readings (Appendix A).

Based on the results of these scans numerous homes and businesses were scheduled for daily monitoring by Seattle Engineering Department personnel. Initially TLVs purchased by Ecology were used and later, Seattle independently purchased its own TLVs for use in this monitoring. This daily monitoring with the TLV proved its value time and again. More than a dozen homes and businesses initially identified through this monitoring as being suspected of having trace levels of methane entering them would later be found with concentrations approaching or exceeding the lower explosive limit and be evacuated. Numerous other homes would later be found with elevated concentrations of methane but below evacuation criteria.

While this routine monitoring of homes and businesses continued, steps were initiated to bring the gas migration under control. In the fall of 1985 Seattle constructed a gas extraction system within the landfill to cut down on the release of gas. Ecology installed approximately 70 gas probes to better define the extent of off-site gas migration. Based on these probes Ecology installed two large gas extraction wells in the neighborhood east of the landfill. Seattle also installed several smaller extraction wells next to homes and businesses that had been found to have the most severe gas entry problems. During the spring of 1986 Ecology installed additional gas probes. Based on this data and home monitoring data several additional extraction wells were installed by Seattle in the neighborhoods around the landfill. These efforts have reduced the concentration of gas around the landfill, particularly to the east where most of the evacuations occurred.

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[1]For full text see January 6, 1986 letter in Appendix A.

A measure of the success of these efforts has been the fact that no TLV readings in excess of 500 ppm had been recorded in any building in the Midway area in the months of August, September and October, 1986. However, in many of the buildings, several of which are checked daily, it is still not uncommon to obtain readings of less than 100 ppm with some as high as 200 ppm using the TLV.

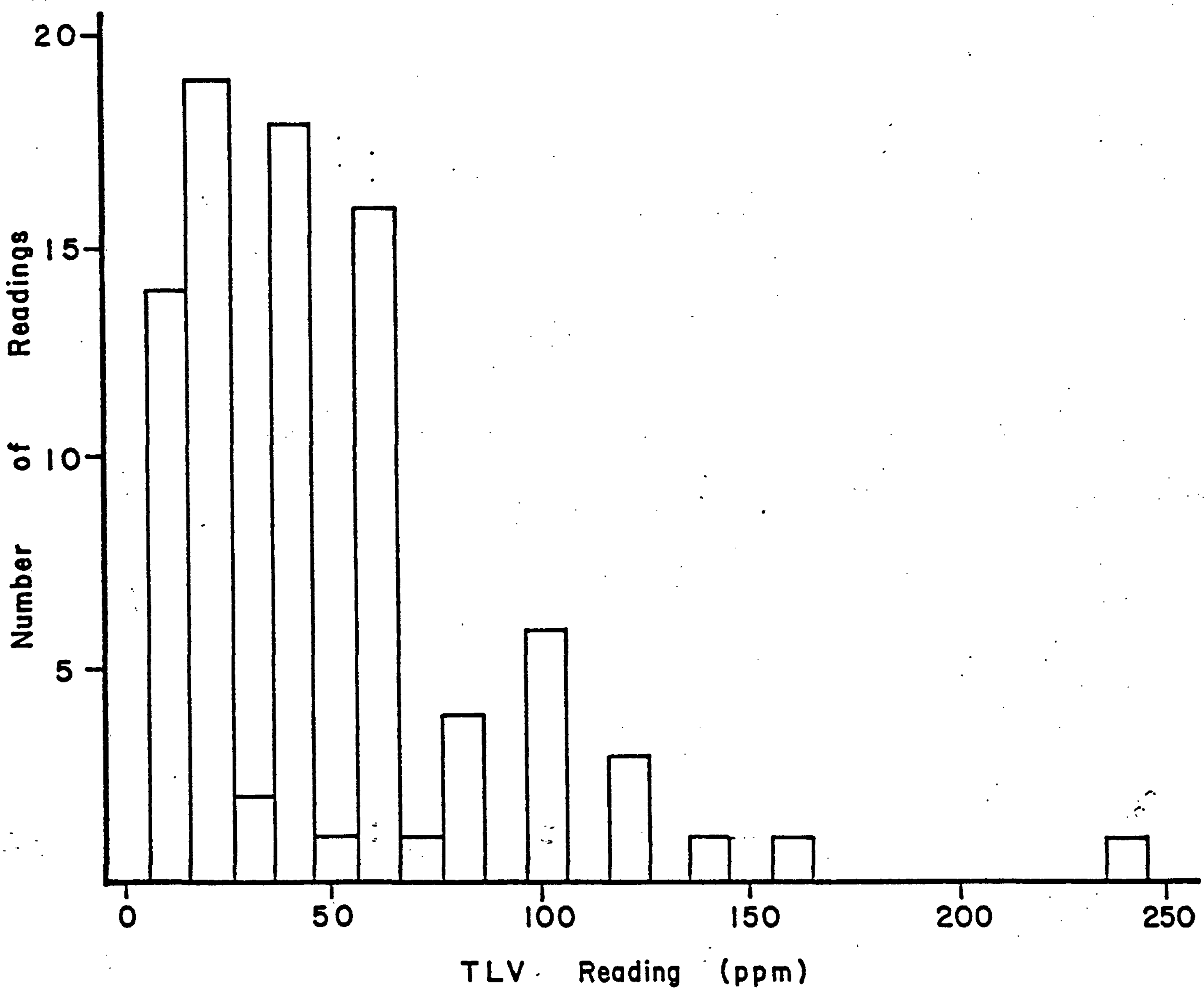
In October, 1986 the Seattle City Attorney's Office hired Heath Consultants to recheck several homes for methane. Heath had been involved previously at Midway for a brief period in the fall of 1985 and had been recommended by Ecology to be retained by Seattle at that time. During the last two weeks of October, 1986 a representative from Heath accompanied Seattle Engineering Department personnel while monitoring the homes in the vicinity of Midway. The Seattle personnel used their TLV meters and the Heath representative used a meter marketed by their company called the Detecto-Pak II (DP-II). This Heath meter operates on a different principle than the TLV, using a hydrogen flame to ionize and hence detect combustible gas rather than the hot filament principle used in the TLV.

During this joint testing twenty-two homes and two elementary schools were monitored. A total of 203 locations were checked in these buildings. Overall, small but measurable amounts of combustible gas were reported by Seattle personnel in just under one-half (44%) of the locations tested and in all but two homes. Heath Consultants recorded only one measurable amount of combustible gas in one home. Due to this apparent discrepancy in results the Seattle-King County Health Department requested that the Department of Ecology do comparison testing of the two meters.

The significance of these most recent home monitoring results is best reviewed by examining in more detail the data accumulated in the home tests with the TLV. Figure 1 presents the frequency of occurrence of the non-zero TLV readings obtained in these home checks. From this figure it can be seen that, using the established screening criteria, more than one-half of these non-zero readings would be considered normal background conditions, warranting no additional follow-up. The remaining readings would warrant further follow-up monitoring. It is important to recognize that these readings are far below the evacuation criteria and lower explosive limit for methane. They are also far below much higher readings obtained in many of the same homes during the winter of 1985-86. Those higher readings and the extent of the problem they defined are not in dispute.

While these latest home monitoring results are encouraging, it is important to recognize that they do not indicate the gas migration problem at Midway has been solved. The on-site gas control system has had to be throttled back due to the threat of starting the landfill on fire. This is because the system is drawing too much air into the landfill which could start a fire through spontaneous combustion. Some probes east of the landfill that had been found to have greatly reduced

Figure 1 : Distribution of Non-Zero TLV Readings Obtained Where Detecto-Pack II Read Zero in Homes During Testing in October, 1986



gas concentrations this summer have recently increased again in concentration. At least one home being checked routinely was recently found to have gas entering it at a concentration 10 times higher than had occurred last summer. This was verified with both the TLV and DP-II instruments. Off-site extraction wells continue to pump substantial quantities of gas out of the ground. The extent of the off-site gas migration is still not fully understood.

Because of these developments, Seattle is proceeding with major improvements in the gas interception system at the landfill. Additional gas probes are also being installed to better define the extent of off-site migration. It is likely that additional off-site extraction wells will be necessary to complete the removal of gas migrating off-site.

HOW THE TLV SNIFFER WORKS

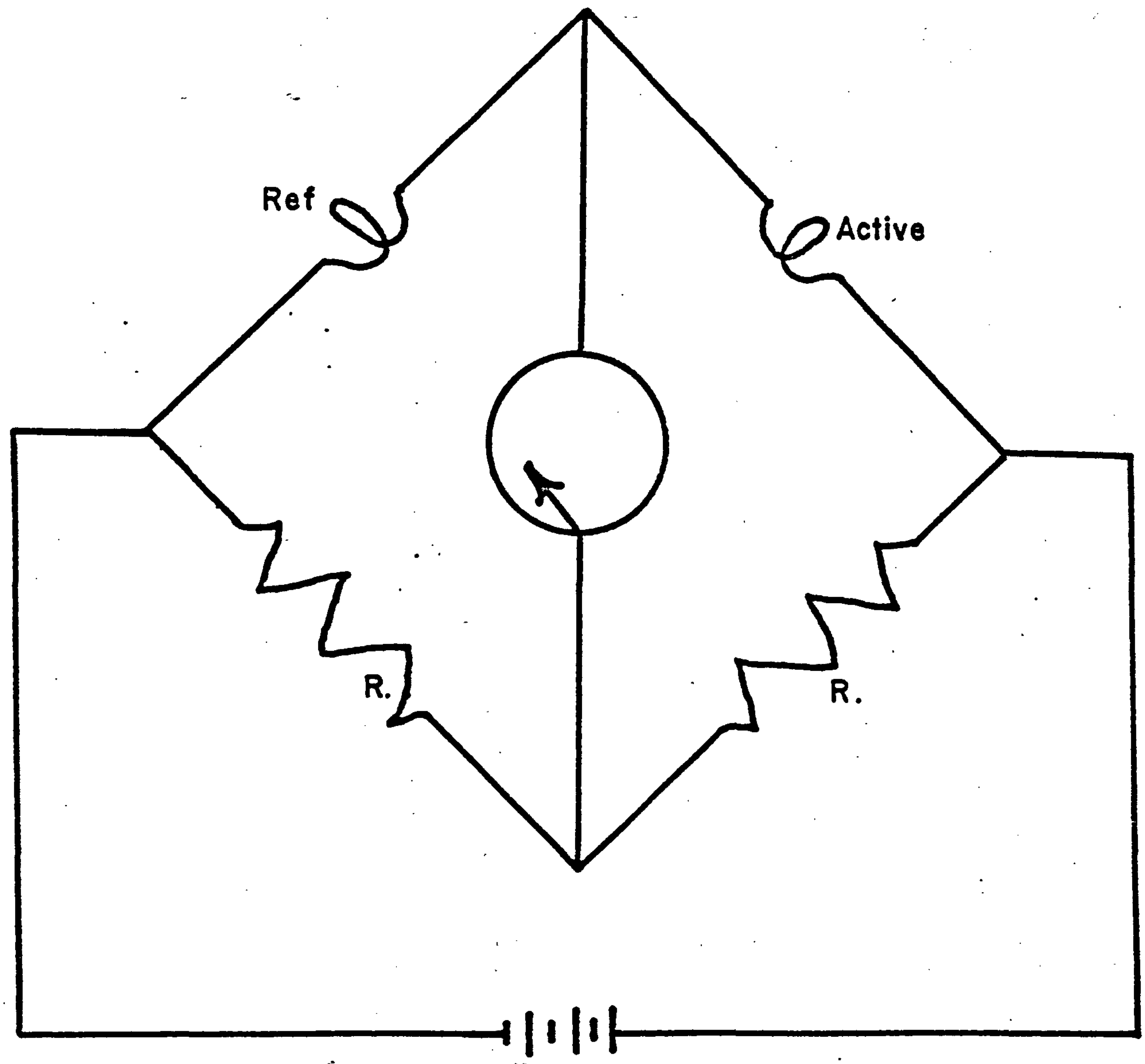
The TLV Sniffer is a portable combustible gas meter manufactured by Bacharach Instruments of Pittsburg, PA. The instrument, first marketed in 1972, has been used in a wide variety of applications including coal mining safety monitoring, arson investigations, industrial safety investigations, and gas pipeline leak detection. The instrument specifications and accessories used for monitoring are included in Appendix D. The heart of the instrument is a hot filament detector which can sense the presence of a combustible gas and translate this into an electronic signal or meter reading.

The hot filament consists of a bead which is made up of many turns of fine wire and covered with a platinum coating. This "active" bead, along with an uncoated "reference" bead is part of an electronic circuit called a Wheatstone Bridge (Figure 2). When current is passed through this circuit in the presence of a combustible gas the active bead will burn hotter than the reference bead. This causes a change in the bead's resistance and an imbalance in the flow of current through the circuit. This imbalance is measured as a meter "reading." The actual concentration of combustible gas this represents is determined by comparing the reading to that obtained with a known concentration of gas. This process, commonly done prior to using the meter, is called calibrating the meter. This calibration is usually done using the same type of combustible gas (such as methane) that is suspected of being present.

It is important to note that this meter is not set up to detect methane exclusively. Other combustible gases, such as gasoline, jet fuel or solvents will be detected by this meter. This is why common household items such as glue, whiteout or a can of paint thinner can cause a meter reading.

The amount of imbalance in the Wheatstone Bridge can be amplified so that different concentrations of combustible gas can be detected. The TLV has three ranges of detection: 0-100 ppm, 0-1000 ppm, 0-10,000 ppm. The lowest scale of 0-100 ppm is intended to be used in a scanning mode. That is, to track down faint traces of combustible gas. Once the source

Figure 2: Simplified Diagram of the Gas Detection Circuit in the TLV Sniffer.



of the combustible gas is detected the upper two scales can be used to quantify the amount present.

The manufacturer specifications indicate that a properly operating and used TLV can be expected to have variations limited to two percent of the reading in question. That is, for a known gas concentration of 200 ppm the meter could read between 196 ppm and 204 ppm and still be within the manufacturer's specifications.

HOW THE DETECTO-PAK II WORKS

The Detecto-Pak II (DP II) is a portable organic vapor detector manufactured by Heath Consultants Inc. of Stoughton, MA. The instrument has been in use since the early 1970s with its primary application in the detection of gas pipeline leaks. The instrument specifications and accessories are indicated in Appendix D. The heart of the instrument is a flame-ionization detector which can sense the presence of ionizable organics such as combustible gas and translate this into an electronic signal or meter reading.

The detector consists of a small chamber where hydrogen gas is burned (Figure 3). This chamber is part of an electrode with a precision charged potential. When a combustible gas is introduced into the chamber the heat of the burning hydrogen partially ionizes (breaks up) the gas molecules into charged particles (ions). These charged particles change the electrode potential which is measured as a meter "reading." The more combustible gas there is present, the greater the number of ions in the chamber and the change in the electrode potential. The actual concentration of combustible gas this represents is determined by calibrating the meter as was described earlier for the TLV.

As with the TLV, it is important to note that the DP-II will detect many types of organic gases, not just methane.

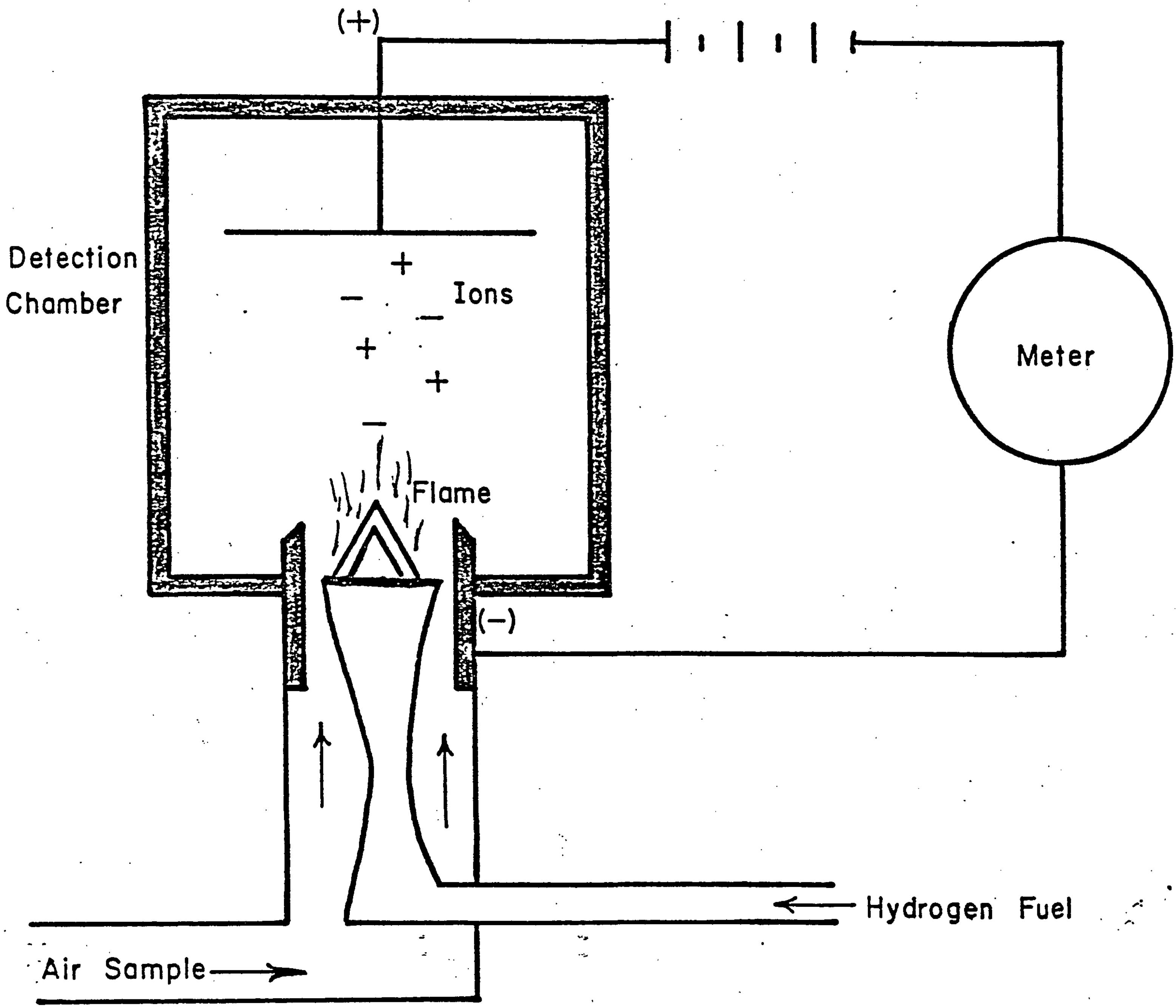
The amount of change in electrode potential can be amplified so that different concentrations of combustible gas can be detected. The DP-II has five ranges of detection: 0-10 ppm, 0-50 ppm, 0-100 ppm, 0-500 ppm and 0-1000 ppm. The lowest scale is used in a scanning mode to pinpoint the source of combustible gas which can then be quantified using the upper scales.

The manufacturer specifications do not list an expected error reading for the meter. The Heath representative at Midway has indicated that the meter is very stable and will give reproducible results, even on its lowest scale.

EXPERIMENTAL METHODOLOGY

The first stage of testing was done with the Century 128 OVA, a portable organic vapor analyzer that utilizes the same flame ionization principle as the DP-II for a detector. These initial experiments were qualitative

Figure 3: Simplified Diagram of Flame Ionization Detector.



in nature and intended to identify the parameters to be evaluated. Later, the DP-II was used for bench scale testing at the Weyerhaeuser Technology Center Laboratory in Federal Way, Washington.

The objectives of this testing program were twofold: (1) to obtain a better understanding of factors that may affect the performance of the TLV and DP-II; and (2) to confirm that the TLV and DP-II can detect methane (when present) in the variety of gas conditions likely to exist at Midway.

To accomplish these objectives a series of 10 liter tedlar (plastic) bags were prepared by Weyerhaeuser according to specifications provided by Ecology. These controlled bag samples were prepared so that factors that could influence meter readings could be isolated and quantified.

The samples were prepared by mixing known volumes of hydrocarbon and carbon dioxide free air with varying volumes of methane, nitrogen and carbon dioxide to produce the target concentrations and conditions listed in Table 1. Actual concentrations, verified by laboratory analysis are reported in Appendix B. The procedures used for these confirmation analyses are described in Appendix C.

In addition to the control bag samples, Black and Veatch, Inc., Ecology's consultant for Midway, collected tedlar bag samples of gas from an extraction well and several gas probes in the vicinity of the Midway Landfill. These samples were utilized to evaluate the two meters' response to the gases present at the site. Probe and extraction well samples were selected rather than samples from buildings for several reasons: (1) The probes and wells sampled have been in place for several months. During this period they have been tested numerous times and have been found to be consistent indicators of the range of conditions present at Midway (2) Since the gas present in these probes and wells is the source of the gas that could potentially enter the homes and businesses at Midway, these samples are felt to be representative of the conditions that could be encountered in these buildings (3) Both the probes and wells are equipped with air tight valves so that a representative sample can be relatively easily collected. Obtaining a representative sample from a crack or hole in a basement would be much more difficult, especially considering the extreme variability past monitoring experience has indicated exists in buildings.

Each bag sample was tested using two TLV Sniffers, two DP-II meters and an OVA 128. The TLVs selected for use were Ecology's #3 meter, used for monitoring probes at Midway, and Seattle's "A" meter, used routinely for monitoring homes. Prior to testing the TLVs were calibrated by Black & Veatch according to manufacturers specifications using 500 ppm standard gas. The DP-II meters and OVA were checked with 100 ppm calibration gas by Heath Consultants and Black and Veatch personnel, respectively, and deemed sufficiently calibrated to test. The bag testing was accomplished by connecting the meter intake to the outlet valve on the bag

Table 1
Target Concentrations for Prepared
Tedlar Bag Standards

Bag Number	Composition
1	500 ppm CH_4 in HC-free air
2	100 ppm CH_4 in HC-free air
3	50 ppm CH_4 in HC-free air
4	21.9% O_2 (from HC-free air source) in N_2
5	18.0% O_2 (from HC-free air source) in N_2
6	16.0% O_2 (from HC-free air source) in N_2
7	12.0% O_2 (from HC-free air source) in N_2
8	Bag #4 + 75 ppm CH_4
9	Bag #5 + 75 ppm CH_4
10	Bag #6 + 75 ppm CH_4
11	Bag #7 + 75 ppm CH_4
12	0.03% CO_2 in HC-free air
13	0.1% CO_2 in HC-free air
14	1.0% CO_2 in HC-free air
15	10.0% CO_2 in zero air
16	Bag #12 + 75 ppm CH_4
17	Bag #13 + 75 ppm CH_4
18	Bag #14 + 75 ppm CH_4
19	Bag #15 + 75 ppm CH_4
20	HC-free air at 50°F
21	HC-free air at 70°F
22	Dry HC-free air
23	Moist HC-free air

Note: HC-free air was made up by adding CO_2 to gas from a tank of compressed air consisting of 79.4 N_2 and 20.6 O_2. See Appendix B for exact concentrations resulting. HC-free air = hydrocarbon free.

with a short length of tygon tubing. The valve was opened and the meter allowed to pump a sample from the bag until the reading had stabilized. Most tests with the TLV were done with it on the 0-1000 scale. For the DP II the 0-10 and 0-100 scales were primarily used.

A complicating factor discovered immediately was that the TLV meters, when zeroed on room air, would drift downscale (negative needle movement) when sampling the hydrocarbon free air made up in the laboratory. This drift was substantial (up to -100 ppm on TLV #3, -220 ppm on TLV A). To compensate for this factor in subsequent readings the TLVs were zeroed on the hydrocarbon free air prior to each bag reading. The two DP IIs and OVA 128 experienced a maximum positive drift of 1 ppm when exposed to the hydrocarbon free air after being zeroed on room air. This drift was deemed inconsequential and the DP IIs and OVA 128 were zeroed on room air for subsequent readings.

A second complicating factor was one of the TLVs tested, the TLV A, used by Seattle, was unstable on the 0-100 scale, indicative of an internal problem on this scale. The meter, however, could be stabilized on the 0-1000 ppm scale and that scale was used for subsequent readings.

All meter readings were witnessed by a representative from Heath and Ecology. The results were recorded in a bound notebook for future reference.

TEST RESULTS

The following provides a data summary and brief discussion of the results of the comparative tests performed. Additional data is presented in Appendix B for those desiring more detailed information on the tests performed. All values presented are in parts per million on a volumetric basis unless otherwise noted.

Standards Detection

A series of standards were prepared to test each meter's ability to accurately detect various concentrations of methane. The results of these tests are reported in Table 2. These results indicate that both types of meters were able to detect methane at concentrations ranging from 37 to 520 ppm. One exception was TLV A failed to detect the second 100 ppm standard tested. It is not known why this occurred, especially since it was able to detect the first 100 ppm standard. This may be related to this meter's instability noted earlier. Using the lab data as the basis for comparison, the percent error for both types of meters was considerable, although the DP II faired somewhat better than the TLV in this regard.

Table 2
Results of Standards Tests - Methane (ppm)

Sample #	#12	#3	#8	#2A	#2B	#1
Target Conc.[b]	0	50	75	100	100	500
Lab Titration[c]	<10	37	37	120	114	520
TLV-3	a	110	75	140	60	710
TLV-A	a	160	90	150	0	860
DP II-1	0	46	74	94	95	840
DP II-2	0	50	82	140	100	440

a. Down scale drift occurred relative to room air. Used to zero TLVs for subsequent readings.

b. From Table 1.

c. Actual methane concentration as verified by lab analysis.

Effect of Depleted Oxygen

An early theory suggested as to why the TLV was indicating readings in homes while the DP II was not was that the TLV was responding to a depleted oxygen condition.

Less than normal oxygen concentrations have been measured in gas probes and at suspected gas entry points in some buildings. To test this theory a series of samples were prepared with the oxygen levels depleted by adding excess nitrogen to them. The results of testing these samples, reported in Table 3, indicate depleted oxygen causes the TLV to drift downscale, not upscale as hypothesized. A slight upscale drift of less than 1 ppm was observed with the DP II, possibly due to minor gas contamination not detected by the lab.

Because depleted oxygen conditions can occur, the ability of the meters to detect methane under this environment was examined. This was done by preparing samples with the oxygen depleted as discussed above and the spiking them with a known amount of methane. The results of these tests indicate both types of meters can detect methane under depleted oxygen conditions. One exception is that the DP II cannot operate under extreme oxygen depletion as the hydrogen flame required for its use will not burn. This is noted in the table as "flame out" in the 11.7% oxygen test. Although this should not present a problem in most home monitoring situations as sufficient oxygen is usually supplied through the normal air exchange that occurs in a home, it could present a problem in probe monitoring. To overcome this a probe sampling technique needs to be developed which introduces a known amount of oxygen into the sample so that flame out would not occur.

Effect of Elevated Carbon Dioxide

Aside from methane, carbon dioxide is the other major component of landfill gas. Elevated concentrations of carbon dioxide have been measured in gas probes at Midway. The effect of elevated carbon dioxide on meter performance was examined using gas samples with various concentrations of carbon dioxide. These results, reported in Table 5, indicate a strong upscale response on the TLV to the presence of carbon dioxide. The DP II had only a minor upscale response of less than 1 ppm.

The response of the TLV to carbon dioxide was so substantial that a sample of room air was obtained to determine if this was the cause of the downscale drift reported earlier. This sample, taken early in the first day of testing when several people were in the room, indicated the room did in fact contain carbon dioxide nearly two and one-half times greater than the prepared hydrocarbon free air and probably was a major contributor to the downscale drift.

To better characterize the TLV response to carbon dioxide available samples were compiled, where no methane had been detected and the carbon dioxide content was known. This data, summarized in Table 7, shows a clear increase in meter readings as the carbon dioxide concentration increases for both TLVs tested. As illustrated in figure 4, the

Table 3
Results of Depleted Oxygen Tests

Sample #	#4	#5	#6	#7
Oxygen %	20.6%	17.6%	15.5%	11.7%
Target Conc.	0	0	0	0
Lab Titration	< 10	< 10	< 10	< 10
TLV-3	a	-40	-10	-70
TLV-A	a	-110	-40	-220
DP II-1	0	0.2	0.1	FO[b]
DP II-2	0.9	0.2	0.2	FO[b]

a Downscale drift occurred relative to room air. Used to zero TLV's for subsequent readings.

b Flame out.

Table 4
Results of Testing Depleted Oxygen Samples
Spiked with Methane

Sample #	#8	#9	#10	#11
Oxygen (%)	20.6%	17.6%	15.5%	11.8%
Target Conc.	75	75	75	75
Lab Titration	37	74	58	49
TLV-3	75	90	100	20
TLV-A	90	80/85a	60	80
DP II-1	74	76	84	FO[b]
DP II-2	82	77	100	FO[b]

a Replicate
b Flame out

Table 5
Results of Elevated Carbon Dioxide Tests

Sample #	#12	#13	#14	#15
Carbon Dioxide %	0.025%	0.12%	1.05%	10.4%
Target Conc.	0	0	0	0
Lab Conc.	<10	<10	<10	<10
TLV-3	a	20	180	440
TLV-A	a	50	410	810
DP II-1	1.0	0	0	0.4
DP II-2	0	0.5	0.1	0.2

a Down scale drift occurred relative to room air. Used to zero TLV's for subsequent readings.

Table 6
Results of Testing Samples Elevated in Carbon Dioxide and Spiked with Methane

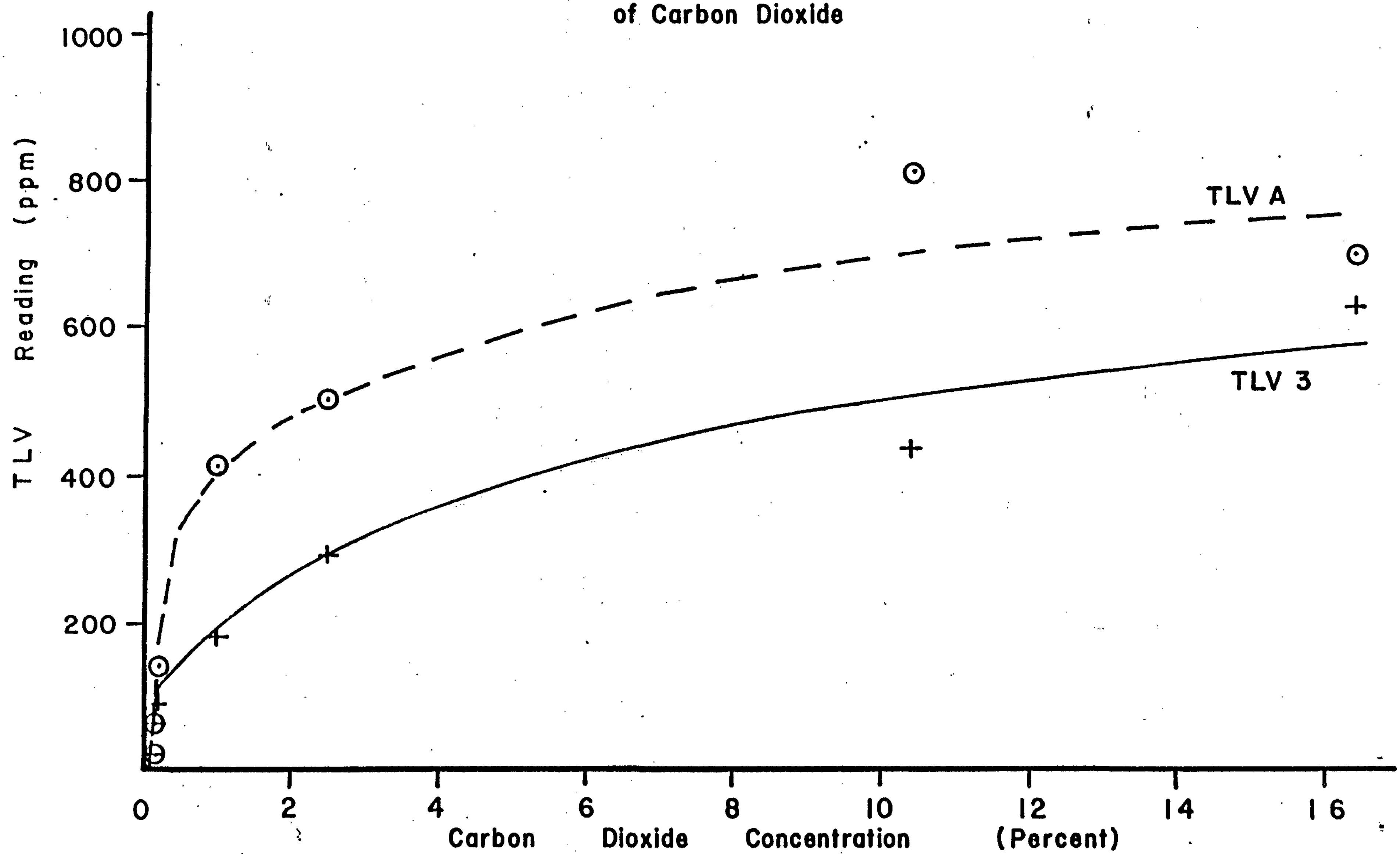
Sample #	#8	#17	#18	#19
CO_2 %	0.037%	0.104%	1.16%	10.8%
Target Concentration	75	75	75	75
Lab Concentration	37	70	78	86
TLV-3	75	110	210	480
TLV-A	90	120	370	800
DP II-1	74	76	76	80
DP II-2	82	80	78	96

Table 7
Summary of TLV Readings for Samples
with Elevated Carbon Dioxide and No Methane

Sample	CO_2%	HC-free[a] CO_2%	Relative[b] CO_2%	Meter Reading(ppm) TLV-A	Meter Reading(ppm) TLV-3
2D	0.049	0.028	0.021	10	10
#13	0.12	0.025	0.095	50	20
92M	0.20	0.042	0.158	140	90
#14	1.05	0.025	1.025	410	180
66S	2.58	0.042	2.538	500/440[c]	290
#15	10.4	0.025	10.375	810	440
69S	16.4	0.042	16.358	700	630

a Concentration of CO_2 in hydrocarbon free air used to zero meter.
b CO_2% - HC-free CO_2%
c Replicate

Figure 4 : Response of TLV 3 and TLV A To Increasing Concentrations of Carbon Dioxide



response was non-linear, asymtotically approaching an upper limit that is different for each meter.

The ability of the two types of meters to detect methane in elevated carbon dioxide conditions was also examined. This was done by spiking samples elevated in carbon dioxide concentration with known amounts of methane. The results of testing these samples are reported in Table 6. The tests indicate that both meters can detect methane in the presence of elevated carbon dioxide. When compared to the results reported in Table 5, it appears the TLVs were adding the methane concentration to the already elevated meter readings caused by the carbon dioxide. This was confirmed by probe testing reported later.

Insufficient data was generated to determine if this effect is strictly additive or only some fraction of the methane is added to the carbon dioxide response.

The strong response of the two TLV's tested to carbon dioxide was unanticipated. Discussions with the manufacturer indicate this response has not been reported before. Since this feature was not specifically designed for the TLV it is likely that different meters will experience different carbon dioxide sensitivity as was illustrated by the differing results of the meters tested.

The strong response of the TLV to carbon dioxide could result in it not detecting methane. This would happen if the meter were zeroed in a higher concentration carbon dioxide atmosphere (such as a crowded room) and then transported to a lower carbon dioxide atmosphere to search for methane. While this could occur, the down scale drift that would occur due to the reduced carbon dioxide concentration would probably be picked up by an experienced operator and an appropriate meter adjustment made.

The characteristic of the TLVs tested to detect carbon dioxide in addition to methane is not necessarily detrimental with respect to landfill gas monitoring. As noted earlier, carbon dioxide is a major component of landfill gas and elevated carbon dioxide readings may be indicative of the potential for methane migration to occur as well. Thus, this sensitivity to carbon dioxide may actually enhance the TLV's ability to scan for the presence of landfill gas. It is important to note, however, that the mere presence of elevated carbon dioxide levels is not necessarily an indication of landfill gas. Elevated levels of carbon dioxide commonly occur in soil due to the limited exchange that occurs between the soil air and atmosphere.

Effect of Temperature

Several users of the TLV have reported that often when walking with the meter from the cool outside into a warm building, the meter will drift upscale. This effect was examined qualitatively by measuring the TLV's and DP-II's response to two samples of air at different temperatures. To perform this test two tedlar bags were filled with the same hydrocarbon free air. One was kept inside at a temperature of approximately

70°F, the other was placed outside at a temperature of approximately 50°F. The instruments were zeroed on the warm air sample and then taken outside to measure the cool air sample. Then the instruments were left outside for about 10 minutes to equilibriate with the outside temperature. The instruments were then zeroed on the cool air sample and brought inside to read the warm air sample. The results are reported in Table 8.

Table 8: Meter Response to Temperature Changes

	Warm (70°F) to cool (50°F)	cool to warm
TLV-3	-70	+30
TLV-A	-40	+10
DP II-1	+0.6	-0.5
DP II-2	0	-0.5

This test confirmed that when transferred from a warm to a cool location, the TLV's tested exhibited a downscale drift. The immediate effect of this transfer on the DP-II's was minimal, although a continued downscale drift was evident as these meters cooled down. Similarly, when the cooled instruments were transferred inside to measure the warm air the TLV's exhibited an upscale drift. The immediate effect on the DP-II's was minimal but, based on discussions with the Health representative, one could expect a continued upscale drift as the instrument warms up.

Effect of Moisture

Some of the points checked in buildings are sumps and drains where considerable moisture can be present. The effect of moisture on instrument response was qualitatively examined by measuring two samples at different moisture contents. The samples were prepared by filling two tedlar bags with the same hydrocarbon free air. Approximately two milliliters of warm water was injected into one bag and allowed to reach equilibrium. The instruments were zeroed on the dryer air and then used to sample the moist air. Similarly, the instruments were zeroed on the moist air and the dry air was sampled. The results are reported in Table 9.

Table 9: Meter Response to Moisture Changes

	Dry to Moist	Moist to Dry
TLV-3	+200	-210
TLV-A	+340	-340
DP II-1	-0.6	+0.4
DP II-2	0/0(a)	0

(a) Replicate test

As indicated in this table, the TLVs tested exhibited a strong upscale response when exposed to the moist air sample tested. The DP II meters tested exhibited only a minor response. This indicates when using the TLV, low concentration readings from moist sumps or drains should be viewed with caution, subject to further verification testing.

Probe Test Results

The data presented up until now was intended to examine the effect of individual factors on instrument performance. To examine the combined effect of several of these factors at once gas samples were obtained from one of the extraction wells and six probes in the vicinity of Midway. The sampling points were selected because they represent the range of conditions found in the soil gas at Midway.

The response of both types of instruments to these samples is reported in Table 10. Once these initial readings were obtained, all but one sample was spiked with a known amount of methane. The response of the instruments to these spiked samples is also reported in Table 10.

These results indicate that both the TLV and DP-II were able to detect methane when it was present in the gas samples, either as collected or after spiking. Exceptions were those probes where insufficient oxygen was present to sustain the hydrogen flame in the DP-II. In those cases the DP-II experienced flame out before a stabilized reading occurred. In nearly all probes the TLV overestimated the amount of methane present, presumably a reflection of its response to the elevated concentrations of carbon dioxide present. The DP II overestimated the methane concentration in some cases and underestimated it in others.

Miscellaneous Factors Possibly Affecting Instrument Performance

While accompanying the Seattle personnel monitoring homes the Health consultant noted several techniques being used that could cause either instrument to exhibit meter drift. These techniques, described below, were qualitatively examined for affect on instrument performance.

Table 10
Summary of Instrument Responses in ppm to Probe & Extraction Well Gas Samples - As Collected and Spiked with Methane

Sample Lab Conc.	2D <10	2D Spiked 53	92M <10	92M Spiked 49	66S <10	66S Spiked 90
TLV-3	10	160	90	220	290	360
TLV-A	10	240	140	240	500/440[a]	550
DP II-1	0	74	0	58	0	52
DP II-2	0	87	0	58	0	52

Sample Lab Conc.	69S 10	69S Spiked 120	61S 520	61S Spiked 1010	E2 6000	E2 Spiked 7020	78S 6700
TLV-3	630	720	1200	1300	8000	9500	6800
TLV-A	700	840	1100	1500	6500	7500	4900
DP II-1	FO	FO	FO	FO	900	900	FO
DP II-2	FO	FO	FO	FO	>1000	>1000	FO

a Replicate tests.

One common technique used is for the instrument carrier to zero the meter prior to entering a home by holding it by the handle. Later, as the day wears on the carrier will often grasp the case of the instrument and support it against the body. For the DP II this was found to have no affect on instrument performance. Both TLVs however, experienced an upscale drift in response to this treatment, probably in response to the warming of the instrument by body heat.

While monitoring a home often the instrument ends up slightly tipped as the carrier bends over to take a reading. An extreme case of the effect of this tipping was modeled by tilting the instruments 45° back and forth. Both DP II meters exhibited an immediate 0.5 ppm upscale response when tilted. The TLVs were inconsistent. TLV-3 showed no effect. TLV-A exhibited an immediate 60 ppm response up or down scale, depending on which way it was tipped. This is not unexpected as the TLV's manufacturer has indicated tipping the instrument can cause a meter response.

Lastly, many of the places being monitored in buildings are cracks or holes in floors and walls. When monitoring these points it is common practice to push the instrument probe into these crevices to obtain a reading. This can result in restricting flow to the instrument. The effect of such a restricting was modeled by using a finger to partially obstruct the instrument intake. This resulted in a small upscale drift on one DP II and no change on the other DP II. In contrast, the TLVs experienced a slow upscale drift up to 80 ppm for TLV-3 and 100 ppm for TLV-A. It was noted by Heath that one of the TLVs in use by Seattle personnel was equipped with probe that had been cut off so that side entry holes no longer existed. This would make it much easier to restrict instrument flow and may have resulted in artificially high readings being reported. This probe has since been repaired.

Appendix A

- January 6, 1986 Letter Setting Action Levels
- Home Monitoring Receipt
- March 24, 1986 Midway Landfill Newsletter
- June 5, 1986 Midway Landfill Update

City of Seattle
Charles Royer, Mayor
King County
Randy Revelle, Executive

Seattle-King County Department of Public Health
Bud Nicola, M.D., M.H.S.A., Director

RECEI

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DEPT. OF ECOLOGY
OLYMPIA, WA.

January 6, 1986

Mr. Richard Owings, Director
Solid Waste Division
Engineering Department
City of Seattle
Sesattle, WA 98104

Dear Rich:

For the past few months, we have been trying to reach consensus on the action levels for methane in houses around Midway Landfill. Recently, representatives of the Department of Ecology, Kent Fire Department, your utility and the Health Department reached agreement. These criteria are substantially the same as we have been using since last August.

GAS ACTION LEVELS INSIDE HOMES/BUSINESSES

(Methane Gas Readings Taken From the Highest Concentrations Found in a Building Unless Otherwise Noted)

0-50 ppm	Consider Ambient Air; Normal Condition
50-100 ppm	Monitor as Frequently as Staff Size Permits
100-500 ppm	Monitor Daily
500 ppm and up	Monitor Daily, Seal Cracks, Highlight Home on Data Sheet, Request Owner to Ventilate
1000 ppm and up	Verify with 2nd Meter and Methane Unit, Seal Cracks, Install Alarm, Fan, Monitor Daily, Notify Health Department and Kent Fire Dept.
5000 ppm and up in atmosphere	Evacuate, Call 911
10000 ppm and up in wall or small confined space	Evacuate, Call 911
40000 ppm and up	Point Source, Evacuate, Call 911

Because the decision to evacuate is far more serious than other decisions, it deserves special note. Whenever levels are found which meet the criteria for evacuation, the Health Department (business hours) or the Fire Department (after business hours) should be called. The inspector should explain the situation and describe any mitigating circumstances (see attached list by Pete Kmet for examples). At that point, the Health or Fire Department will make a decision. If the decision is to evacuate, a uniformed Fire Department employee should be called by the investigator. If possible, your staff should explain to evacuees that there is a great deal of media interest in their evacuation. We can provide them a list of media contacts. Unless told otherwise, we will keep their name and address confidential.

Environmental Health Division Room 1510 Public Safety Building Seattle, Washington 98104 (206) 587-2722

We are very happy to finalize these criteria. They provide the field staff with the definitive guidelines needed to interpret methane data and they give us flexibility to reach the unusual situation.

Very truly,

Chuck K

Chuck Kleeberg, Director
Environmental Health Division

CK:rb
Att.

cc: Marvin Berg, Assistant Chief
Kent Fire Department
Mark Edens, Seattle Solid Waste Utility
Gale Starr, Seattle Solid Waste Utility
David Bradley, Washington State Department of Ecology

Seattle
Engineering Department

Eugene V. Avery, Director of Engineering
Charles Royer, Mayor

DATE:

TO: Resident

FROM: Seattle Engineering Department

SUBJECT: Methane Gas Testing

On this date we have checked your home for the presence of methane gas. Our instruments indicate that the levels of methane do not exceed ________ppm.

Methane is a colorless, odorless, tasteless, non-toxic gas which is naturally produced when garbage decomposes. Methane is not considered dangerous below 40,000 ppm. At levels above this there is danger of explosion, fire, and the displacement of oxygen.

If you have any questions about this monitoring program, please feel free to contact Mark Edens of the Seattle Engineering Department at 625-2324 or Greg Bishop of the Seattle/King County Health Department at 587-2722.

Sincerely,

Monitor

GAS ACTION LEVELS INSIDE HOMES/BUSINESSES

(Methane Gas Readings Taken From the Highest Concentrations Found in a Building Unless Otherwise Noted)

0-50 ppm	Consider Ambient Air; Normal Condition
50-100 ppm	Monitor as Frequently as Staff Size Permits
100-500 ppm	Monitor Daily
500 ppm and up	Monitor Daily, Seal Cracks, Highlight Home on Data Sheet, Request Owner to Ventilate
1000 ppm and up	Verify with 2nd Meter and Methane Unit, Seal Cracks, Install Alarm, Fan, Monitor Daily, Notify Health Department and Kent Fire Dept.
5000 ppm and up in atmosphere	Evacuate, Call 911
10000 ppm and up in wall or small confined space	Evacuate, Call 911
40000 ppm and up	Point Source, Evacuate, Call 911

Seattle
Engineering Department

Eugene V. Avery, Director of Engineering
Charles Royer, Mayor

MAR 28 1986

March 24, 1986

MIDWAY LANDFILL NEWSLETTER

Monitoring for Methane Gas

The Seattle Engineering Department has been working to control the underground movement of methane gas from the Midway Landfill. During the fall of 1985, a gas extraction system was installed around the perimeter of the landfill. During January 1986, the City of Seattle installed five vent wells in the neighborhood surrounding the landfill, and the Department of Ecology installed two vent wells. Inspectors from the Seattle Engineering Department have been monitoring inside of homes and commercial buildings for the presence of methane.

What kinds of meters are used?

Two kinds of meters are used to measure landfill gas that may be in homes. Both measure combustible gas (gas capable of burning), including methane. For routine monitoring, inspectors use an instrument called a TLV sniffer. This kind of meter measures the amount of combustible gas in parts per million, or ppm.

When an inspector finds more than 10,000 ppm of gas using a TLV sniffer, another test may be done with a different meter, a J.W. Gas Pointer. This instrument is better for measuring high levels of combustible gas. The gas pointer measures by percentage rather than by ppm. The lowest level of gas that the gas pointer can detect is 1/10% (1,000 ppm).

What levels of combustible gas are considered normal?

The Seattle-King County Health Department considers 50 ppm or less to be n[illegible], or what can be expected in any home that doesn't have a special source of [illegible]. For example, a meter will read as high as 50 ppm if a person breathes directly on the measuring wand. If more than 100 ppm are found, periodic testing or other measures are taken by the inspectors.

What levels of methane are considered dangerous?

Methane can explode when it is concentrated in air between 4.8% and 18% (48,000 ppm and 180,000 ppm), and will burn at concentrations higher than 18%. The Seattle-King County Health Department may evacuate families when concentrations are 1/2% (5,000 ppm) in the atmosphere, 1% (10,000 ppm) in a wall or small confined space, or 4% (40,000 ppm) at a point source even though these are below the lower explosive limit of 4.8% in the atmosphere. With the owners's permission, inspectors may try to stop the methane from collecting before evacuating people from their homes, even though levels are high. They may seal [illegible] or install a ventilation system.

Why do meters sometimes give false readings?

TLV sniffers are very sensitive instruments. They may show a positive reading when no gas is present because of steam or a change in temperature, or because a filter is not clean or the line is plugged. They occasionally malfunction, even though once a week they are recalibrated by a certified person. This is why, when a meter indicates a high level of gas is present, inspectors verify the reading with a second TLV meter, and then with the J.W. Gas Pointer.

What other gas might be present, if not landfill gas?

There may be other sources of combustible gas in a home that are detected using a TLV meter, a J.W. Gas Pointer, or wall-mounted alarm. Some examples are:

cigarette smoke	natural gas leak
auto fumes	inefficient fireplace or wood-burning stove
gasoline	hair spray
propane	solvents

Also, steam or a change in temperature may cause the TLV meter to indicate gas is present, when actually there is no gas.

Where is methane most likely to enter a home?

Methane follows the path of "least resistance." The most likely place for the gas to enter a home is through the seam between floor slabs and footings. Other likely entry points are large cracks or holes in a crawl space or a subterranean basement floor, or around the outside of pipes.

Why are wall-mounted meters installed near the ceiling?

Wall-mounted meters are intended to monitor gas present in the general atmosphere, not at a point source such as crack in the floor or wall.

Methane is lighter than air. When it enters a room through a crack, it rises and collects at the ceiling. A meter installed near the floor would not detect gas entering from a point on the opposite side of the room as quickly as it would if the meter were located near the ceiling.

What is the status of the vent wells?

The five vent wells installed by the City of Seattle in the neighborhood surrounding the Midway Landfill continue to effectively control levels of gas for several hundred feet around each well. Monitoring indicates there is no methane in the commercial buildings west of the landfill with vent wells, and little or no methane in homes near the three vent wells on the east side.

To have your home or commercial building tested:

Call the Midway Service and Information Office at 946-4458, or call the City of Seattle's Solid Waste Utility at 625-2324, if you would like your home or building tested.

ANDREA BEATTY RINIKER
Director

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

Mail Stop PV-11 • Olympia, Washington 98504-8711 • (206) 459-6000

Midway Landfill Update - June 5, 1986

- Reporting on the Status of Activities as of June 2, 1986 -

WHAT WERE THE RESULTS OF THE SURFACE WATER TESTING DONE BY ECOLOGY IN APRIL?

Ecology sampled surface water from nine different locations on the westside of the Midway Landfill in April of this year. Four samples were taken around the wetlands near Parkside Elementary School and the rest to the west and south of the school. These samples were run through several tests: conductivity, pH, temperature, metals, volatile organics and coliform. The results from the tests show no evidence that leachate is present. However, they are incomplete at this time and the remaining results will be reported in the Update as soon as they become available.

Conductivity measures the overall quality of a water sample and indicates whether manmade or natural substances are dissolved in the water. The test is commonly used to check for leachate, which has a high conductivity. Conductivity readings for these samples ranged from 115 - 305. A reading of 700 or above would alert us to investigate further for leachate. For comparison, water from Water District 75 and the City of Kent has conductivity readings that range from 80 - 180.

Testing for pH determines the acidity or alkalinity of water samples. The pH reading for pure water is 7.0, vinegar is acidic with a pH of 3.0, and laundry detergent is alkaline with a pH of 11. The pH readings for these samples were within the expected range near neutral, ranging from 5.7 to 7.1. Most of the readings were between 6.0 and 6.5.

The nine samples were tested for eight different metals: copper, zinc, iron, nickel, chromium, cadmium, lead, and manganese. The sample results were compared to the standards for surface water and drinking water quality set by the Environmental Protection Agency and the Washington State Department of Social and Health Services. Four samples contained elevated concentrations of metals, particularly iron, manganese and copper. The presence of these metals is not unusual in surface water, but can be a sign of leachate. At the levels found in these samples, however, these metals are not a health hazard but would cause stains and a bad taste.

Testing for volatile organics revealed traces in two of the nine samples. One of these sampling locations was a methane gas probe. The sampling results indicated that four contaminants were present in very small concentrations that were lower than EPA standards for both drinking and surface water quality. The other sample was taken at the site of an old gasoline station, which is currently an operating automobile business. It was not surprising to find elevated levels of benzene, toluene, ethylbenzene and total xylenes, which are all components of gasoline. In this sample, only benzene was present in amounts above the EPA drinking water standards, but below the EPA surface water quality standards.

The samples were also tested for fecal coliform , a bacterium present in the intestinal tracts and feces of humans and animals. Large amounts of fecal coliforms in water can indicate a recent sewer leak or septic tank failure, but are not usually found in landfill leachate. One sampling location, near Highway 99 showed exceptionally high levels of fecal coliforms. Ecology has contacted the Seattle-King County Department of Public Health about these results, because the Health Department has been working to eliminate the source of the problem.

Two other locations had higher than expected coliform counts which may have been caused by animals in the area. The coliform counts in these two samples made the water unacceptable for drinking under the Washington Water Quality Act and EPA drinking water standards, but the water was still acceptable for agricultural or recreational use.

In conclusion, the limited sampling of surface water shows no evidence that leachate is present in this area west of the landfill. However, the Department of Ecology took a second round of samples both east and west of the landfill on May 29, to be tested for conductivity, pH, and 35 volatile organics. More comprehensive testing will be done over the next year and will include ground and surface water testing.

The sampling results are available for review at the Midway Information Office and the repositories at the Kent and Des Moines libraries.

INFORMATION ON THE TLV METERS

Recently, some questions have arisen about the meaning of combustible gas readings near 100 parts per million. The Department of Ecology, Seattle Engineering Department, and the Kent Fire Department all use the TLV meter to test gas probes and to monitor homes. These machines are extremely sensitive to combustible gas in the air and are usually used to detect gas leaks. Because of their sensitivity in the 0-100 ppm range, vapors other than methane can cause readings on the meters. For example, cupping the probe in your hand can sometimes cause a reading as high as 70 ppm; vapor from your coffee can cause a reading of 70 ppm; and if the probe is placed near your mouth, your breath can cause it to register 40 ppm. In addition, staff set the meter on "zero" outside of a home; entering a home that has a higher temperature and humidity than outside air will cause the meter reading to rise. This means that readings of 100 ppm in your home could be caused by sources other than methane, like exhaust from your furnace or odors from cooking. This is why a home with readings below 100 ppm is not monitored daily and a reading below 50 ppm is considered normal or "background."

The TLV meter measures combustible gas at levels up to 10 percent, or 10,000 parts per million. For higher levels, field staff use an instrument called a MSA 60.

Appendix B

- Bag Sample Analyses
- Summary of Instrument Readings

Table B1
Summary of Tedlar Bag Analyses Performed by
Weyerhaeuser Technology Center Laboratory

Bag Number	CO_2(%)	CH_4 (ul/l)		O_2(%)
1	0.046	520		-
2a	0.034	120		-
2b	0.046	114		-
3	0.043	37		-
4	(same as air samples)	-		-
5	0.029	-		17.6
6	0.029	-		15.5
7	0.033	-		11.7
8	0.037	37		20.6
9	0.13	74		17.6
10	0.042	58		15.5
11	0.041	49		11.8
12	0.025	-		-
13	0.12	-		-
14	1.05	-		-
15	10.4	-		-
16	(same as bag #8)			
17	0.104	70		-
18	1.16	78		-
19	10.8	86		-
20a	(warm HC-free air)	-		-
21	(cool HC-free air)	-		-
22	(dry HC-free air)	-		-
23	(moist HC-free air)	-		-
Air 2	0.025	-		-
Air 3	0.025	-		-
Air 4	0.032	-		-
Air 5	0.028	-		-
Air 6	0.042	-		-
Air 7	0.043	-		-
Conference Room	0.072	-	(Spiked)	-
2D	0.049	< 10	53	-
66S	2.58	< 10	90	-
61S	12.1	520	1010	-
E2	5.85	6000	7020	-
69S	16.4	< 10	120	-
92M	0.20	<10	49	-
78S	19.2	6700	-	

Note: Bags 1-19 and air were made up by adding CO_2 and CH_4 (where appropriate) to gas from a tank of compressed air consisting of 79.4 N_2 and 20.6 O_2. This compressed air tested at 10 ppm hydrocarbons. Bags 20-24 were made up using a source of "clean air" piped into lab from outside. This air tested at 10 ppm hydrocarbons.

"-" means not analyzed.

Table B2
Results of Standards Tests(f)

Bag Sample No.	#12	#3	#8	#2A	#2B	#1
Target Concentration(a)	0	50	75	100	100	500
Lab Titration(b)	<10	37	37	120	114	520
TLV 3 (d)	-	110	75	140	60	710
TLV A (d)	-	160	90	150	0/0(c)	860
TLV 3 (e)	-100	10	-35	40	40	660
TLV A (e)	-220	-60	-110	-70	0/0(c)	710
DP II-1 (e)	1.0	46	74	94	95	440
DP II-2 (e)	0	50	82	140	100/100(c)	840
OVA 128 (e)	0.9	57	90	100	84	560
CO_2%	0.025	0.043	0.037	0.034	0.046	0.046
HC-free air used	-	#2	#4	#12	#5	#12

(a) As per Table 1.
(b) Actual concentration measured by lab.
(c) Replicate tests.
(d) Relative to HC-free air which was used to zero meters.
(e) Relative to room air.
(f) Results reported are in parts per million on a volumetric basis unless otherwise indicated.

Table B3
Results of Depleted Oxygen Test

Bag Sample No.	#12	#5	#6	#7
O_2(%)	20.6%	17.6%	15.5%	11.7%
Target Conc.	0	0	0	0
Lab Titration	< 10	< 10	<10	< 10
TLV 3 (a)	-	-40	-10	-70
TLV A (a)	-	-110	-40	-220
TLV 3 (b)	-100	-110	-90	-120
TLV A (b)	-220	-280	-250	-370
DP II-1 (b)	1.0	0.2	0.1	FO(c)
DP II-2 (b)	0	0.2	0.2	FO(c)
OVA 128 (b)	0.9	0.4	0.3	FO(c)
CO_2%	0.025	0.029	0.029	0.033
HC-free air used	-	#3	#3	#3

(a) Relative to HC-free air which was used to zero meters.
(b) Relative to room air.
(c) Flame out.

Table B4
Results of Testing Depleted Oxygen Samples
Spiked with Methane

Bag Sample No.	#8	#9	#10	#11
O_2%	20.6%	17.6%	15.5%	11.8%
Target Conc.	75	75	75	75
Lab Titration	37	74	58	49
TLV 3 (a)	75	90	100	20
TLV A (a)	90	80/85(c)	60	80
TLV 3 (b)	-35	70	80	60
TLV A (b)	-110	60	10	0
DP II-1 (b)	74	76	84	FO(d)
DP II-2 (b)	82	77	100	FO(d)
OVA 128 (b)	90	66	83	FO(d)
CO_2%	0.037	0.13	0.042	0.041
HC-free air used	#4	#5	#5	#5

(a) Relative to HC-free air which was used to zero meters.
(b) Relative to room air.
(c) Replicate tests.
(d) Flame out.

Table B5
Results of Elevated Carbon Dioxide Tests

Bag Sample No.	#12	#13	#14	#15
CO_2%	0.025	0.12%	1.05%	10.4%
Target Conc.	0	0	0	0
Lab Titration	< 10	< 10	< 10	< 10
TLV 3 (a)	-	20	180	440
TLV A (a)	-	50	410	810
TLV 3 (b)	-100	-80	70	340
TLV A (b)	-220	-170	190	580
DP II-1 (b)	1.0	0	0	0.4
DP II-2 (b)	0	0.5	0.1	0.2
OVA 128 (b)	0.9	0.9	0.1	1.6
HC-free air used	-	#2	#2	#3

(a) Relative to HC-free air which was used to zero meters.
(b) Relative to room air

Table B6
Results of Testing Sampling Elevated in
Carbon Dioxide and Spiked with Methane

Bag Sample No.	#8	#17	#18	#19
CO_2%	0.037%	0.104%	1.16%	10.8%
Target Conc.	75	75	75	75
Lab Titration	37	70	78	86
TLV 3 (a)	75	110	210	480
TLV A (a)	90	120	370	800
TLV 3 (b)	-35	10	210	400
TLV A (b)	-110	-100	220	630
DP II-1 (b)	74	76	76	80
DP II-2 (b)	82	80	78	96
OVA 128 (b)	90	95	95	93
HC-free air used	#4	#4	#4	#4

(a) Relative to HC-free air which was used to zero meters.
(b) Relative to room air.

Table B7
Results of Testing Samples from Gas Probes & Extraction Wells

Bag Sample No	2D	61S	66S	69S	92M	E2	78S
O_2% (a)	-	-	-	2.1%	20.2%	15.6%	2.4%
CO_2%	0.049%	12.1%	2.58%	16.4%	0.20%	5.85%	19.2%
Lab Titration	<10	520	<10	<10	<10	6000	6700
TLV 3 (b)	10	1200	290	630	90	8000	6800
TLV A (b)	10	1100	500/440(d)	700	140	6500	4900
TLV 3 (c)	-10	1100	180	530	0	7900	6750
TLV A (c)	-10	930	250	540	0	6350	4750
DP II-1 (c)	0	FO	0	0	0	900/900(d)	FO
DP II-2 (c)	0	FO	0	0	0	>1000	FO
OVA 128 (c)	0.1	FO	0	0	0	>1000	FO
HC-free air used	#5	#6	#6	#6	#6	#6	#6

(a) Based on testing with MSA 361
(b) Relative to HC-free air used to zero meter.
(c) Relative to room air.
(d) Replicate test

Table B8
Results of Testing Samples from Gas Probes and Extraction Wells Spiked with Methane

Bag Sample No	2D	61S	66S	69S	92M	E2
O_2% (a)	-	-	-	2.1%	20.2%	15.6%
CO_2% (a)	0.049%	12.1%	2.58%	16.4%	0.20%	5.85%
Lab Titration	53	1010	90	120	49	7020
TLV 3 (b)	160	1300	360	720	220	9500
TLV A (b)	240	1500	550	840	240	7500
TLV 3 (c)	100	1400	230	600	60	9400
TLV A (c)	100	1100	300	620	70	7300
DP II-1 (c)	74	FO	52	FO	58	900
DP II-2 (c)	87	FO	52	FO	58	>1000
OVA 128 (c)	73	FO	49	FO	45	>1000
HC-free air used	#6	#7	#7	#7	#7	#7

(a) Assumed to be the same as unspiked samples.
(b) Relative to HC-free air used to zero meters.
(c) Relative to room air.

Table B9
Miscellaneous Test Results
(see text for explanation of test methods used)

Test	Warm to Cold	Cold to Warm	Holding Technique	Position	Dry to Moist	Moist to Dry	Restricted Flow
TLV 3	-70	+30	+10	0	+200	-210	+80
TLV A	-40	+10	+40	±60	+340	-340	+100
DP II-1	+0.6	-0.5	-	+0.5	-0.6	+0.4	± 1
DP [illegible]	0	-0.5	0	+0.5	0/0	0	0
OVA 128	-	+0.2	-	0	+0.1	+0.05	- 1
Lab Titration	< 10	< 10	-	-	< 10	< 10	-

Appendix C

Methods Used for Confirmation Analyses by
Weyerhaeuser Technology Center Laboratory

Appendix C

Analytical Procedures Utilized by Weyerhaeuser to Verify Key Bag Contaminants.

Determination of Carbon Dioxide

A 50 ml aliquot of sample is withdrawn from the Tedlar bag and injected through a septum into a "Colourmetric cell" (Colourmetrics, Model 5010). In this cell the carbon dioxide is converted to a strong titratable acid by an aqueous solution of ethanolamine. Base is electrically added to the solution until the colormetric indicator changes from blue to clear at the colormetric endpoint (neutralization point).

The amount of base acquired to neutralize the acid is displayed in "micrograms carbon". The amount of carbon dioxide in the sample is then back-calculated.

Determination of Methane
(Titration Method)

A 50 ml aliquot of sample is injected into a potassium hydroxide solution which removes carbon dioxide. The residual gas passes into a furnace where all hydrocarbons are combusted forming carbon dioxide and water. The amount of carbon dioxide is determined using the colormetric method discussed previously. The amount of total hydrocarbons (which is assumed to be methane) is then back calculated.

(Gas Chromotograph Method)

A one ml aliquot of sample is injected into a column on a Perkins-Elmer Gas Chromatograph (Model 3920). THe column was packed with "Carbosieve" and allowed only C_1-C_3 carbons to elute from column. Heavier compounds, C_4+, could not be analyzed by this technique because they remained in the column.

The carbon ions, produced by the combustion of eluting hydrocarbons, are attracted to a collector plate (FID). The resulting electrical imbalance is registered as a "peak" on the GC strip printout. By measuring the retention time and the area under the peak, the compound can be identified and its concentration calculated.

Results of previous gas analyses indicated that the colormetric method generated more accurate results than the GC/FID method.

Sample EW-2 was analyzed by GC/FID and no other short chain hydrocarbons (C_1-C_3) were detected. The concentration of methane in the samples analyzed by GC/FID, was similar to the concentration calculated by colormetric analysis.

Determination of Oxygen

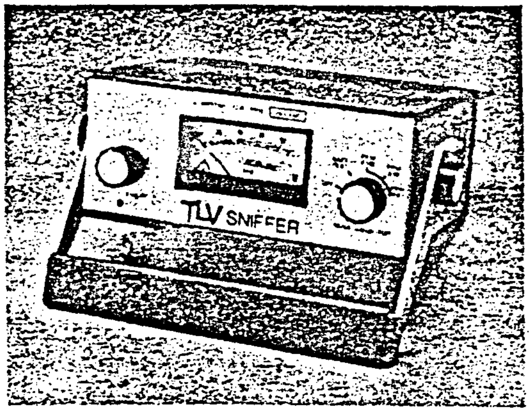
One ml of sample is injected into a Perkins-Elmer 900 gas chromatograph equipped with a CTR molecular sieve and porapak column. As the oxygen elutes from the column the conductivity is measured by an electrical bridge. The mass of oxygen in the sample is proportional to the electrical imbalance and is registered as a peak on the GC strip chart. The amount of oxygen is then calculated based on the retention time and the area beneath the peak.

Appendix D

TLV Sniffer - Specifications and Accessories

Detecto-Pak II - Specifications and Accessories

SUPER SENSITIVE INSTRUMENTS: MODEL TLV SNIFFER



Description:

The TLV Sniffer is an ultra-sensitive precision-made combustible gas indicator.

Wherever flammable liquids are present, the Model TLV is almost indispensable for health, safety and air pollution studies.

The ability of the Model TLV to respond to ppm concentrations of most types of flammable liquid vapors, adds greatly to it's versatility. When calibrated for a specific vapor, the instrument will provide accurate, quantitative readings.

Other vapors can be measured by reference to curves, calibrated in terms of ppm, or percent by volume lower explosive limit. Alternatively, the instrument can be field calibrated for specific vapors. Independent calibrating potentiometers are provided for each measuring range.

Audible alarm, warns if meter needle moves upscale, or drifts below zero setting.

Precision meter, wide-view scale with clear graduations.

Long-life sensor, non-reductive and resistant to poisoning by lead or silicone.

SPECIFICATIONS:

Function	Measurement of low concentrations of flammable vapors, relative to health, safety and pollution control standards
Detector	Catalytic combustion
Standard measuring ranges	0-100, 0-1000 and 0 to 10,000 ppm, hexane*
Special scale ranges	0-300, 0-3000 and 0 to 30,000 ppm, vinyl chloride* 0-500, 0-5000 and 0 to 50,000 ppm, methane*
Min. detectable concentration	2.0 ppm
Sample flow	2 liters/min., nominal
Recorder output	0 to 100 mv into 1000 ohms
Battery capacity	Better than 8 hours continuous operation with 6, size D, Nicad batteries, or approx. 3 hours with 6, size D, carbon-zinc batteries
Construction	Reinforced metal top, end panels and carrying handle, with ABS plastic wrap-around side cover
Dimensions	9" x 3.75" x 6.625" (228mm x 95mm x 168mm)
Weight	5 lb. (2.55 Kg), with Nicad batteries

*Calibration on specific gas available at additional cost of $50.00 per instrument.

Bacharach Instrument Company, *625 Alpha Drive, Pittsburgh, PA 15238 (412) 782-3500*

HOW TO ORDER:

Bach. Code	Description
23-7350	Model TLV, basic instrument, c/w 6 rechargeable Nicad batteries (battery charger not included)
23-7356 (FM)	Model TLV, basic instrument, c/w 6 rechargeable Nicad batteries (battery charger not included) FM approved as intrinsically safe
Optional Accessories	
23-7230	Battery charger, with cord and plug, 115 VAC
23-7353	Battery charger, with cord and plug, 230 VAC
23-7355	Dilution probe assembly, dilutes sample 10 to 1
23-0605	Earphone, with cord and plug

Note: For probes, hoses and spare parts, see section on accessories.

TLV SNIFFER AND ACCESSORIES - PRICE LIST (Effective date: 1/16/86)

#23-7356	FM Bacharach, Model TLV Sniffer	1325.00
#23-7355	Dilution Probe Assembly 10701	153.00
#23-7230	Battery Charger 115ac	49.17
#23-7351	Case for TLV Meter	58.32
#23-7341	Water Trap	58.80
#23-7243	42" Hose	45.00
#23-4850	Wand	23.55

HEATH CONSULTANTS

An Extremely Versatile Gas Search Instrument

DETECTO-PAK® II is a proven, portable/mobile Flame-Ionization Detector designed by Heath to have high sensitivity, compactness, light weight and low maintenance.

DETECTO-PAK® II has been thoroughly field tested by Heath under varied conditions throughout the world and has proven to be the most stable and dependable flame-ionization detector on the market today. Designed to provide greater convenience for the operator, as well as accurate results, it is an extremely versatile detector. DETECTO-PAK® II is easily modified for vehicle mounting to conduct mobile as well as portable surveys. Information about this modification is available upon request.

PORTABLE: Ideal for inspecting transmission lines, business areas, services, building and non-drivable areas of your distribution system.

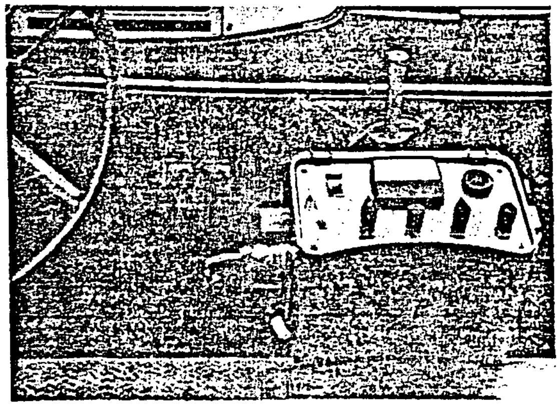
MOBILE: Easy snap-in/snap-out internal mounting and sampling system provides reliable over-the-road data.

DP® II shown in one of many portable applications.

- PORTABLE/MOBILE CONFIGURATION: Change from one to the other accomplished in 10-15 seconds.
- LIGHTWEIGHT: Only 9 lbs. (4.09 Kg) front mounting.
- SENSITIVITY: Five ranges from 0 ppm to 1000 ppm — full scale.
- PUMP INTAKE: Approximately 3 liters per minute.
- READ OUT THRU:
  1) Visual meter to read ppm;
  2) Visual flame out indicator;
  3) Adjustable audible alarm for leak indications.
- IGNITION: Electronic Spark.
- POWER SUPPLY: Rechargeable lead-acid battery—quick change for continuous operation.
- FUEL SUPPLY: Refillable hydrogen-nitrogen bottle complete with pressure regulator and gauges—sufficient for at least 8 hrs.

OPERATING INFORMATION

The DETECTO-PAK® II is an instrument for measuring very small quantities of combustible substances (ppm), utilizing the well-known and proven flame ionization principle. A controlled amount of fuel gas is admitted to a detector cell, along with an air sample drawn by a small sampling pump. The fuel and sample are consumed within the chamber, and ionization occurs when combustible hydrocarbons are present. The rate of ionization is electrically measured and converted to a visual indication of hydrocarbon level.

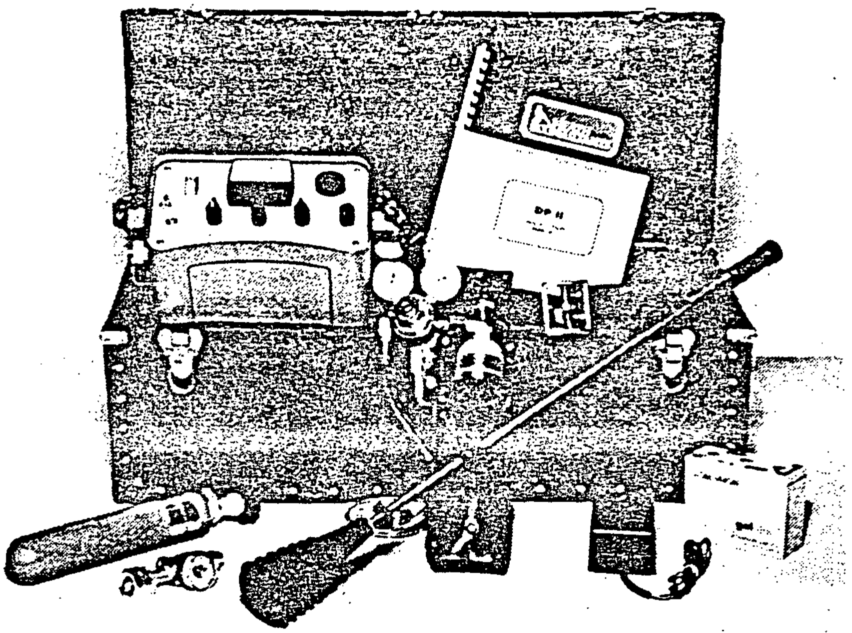


DP® II is shown installed in mobile configuration.

- See back for Specifications and Ordering Instructions.

DETECTO-PAK® II

HEATH CONSULTANTS



SPECIFICATIONS

Weight of Detector:	9 lbs (4.09 Kg)	**Ignition:**	Pulsed high-voltage arc across 2 electrodes
Weight of Belt-Borne Hardware:	4.75 lbs (2.15 Kg)	**Batteries:**	Single, 6 Volt 6 amp-hour, sealed lead-acid battery
Telescopic probe:	Extends from 25 to 41 inches (63.5 cm to 104.14 cm); 1 lb. (.45 Kg)	**Battery Charger:**	Available in 110 Volt or 220 Volt (must specify) 2.75 lbs (1.25 Kg)
Sensitivity:	5 scales, ranging from 0-1000 ppm gas in air	**Lecture Bottle Capacity:**	Approximately 36 liters @ 1750 p.s.i.
Sampling Rate:	3 liters per minute	**Daily Operating Life:**	8 hours (batteries fully charged and fuel cylinder filled to 1750 p.s.i.)
Fuel Consumption:	(40% hydrogen/60% nitrogen) 75 cc per minute, NTP	**Total Shipping Weight:**	36 lbs (16.36 Kg)
Meter Readout:	0-100 mv	**Case Dimensions, H-W-L:**	10.5 x 11 x 23 in. (26.67 x 27.94 x 58.42 cm)
Alarm:	Adjustable, audible alarm for leak indications	**Warranty:**	1 year on parts, excluding battery, 90 days on labor

HOW TO ORDER

Heath No.	Description
1652	Heath DETECTO-PAK® II complete unit includes: detector with rechargeable battery, telescopic probe assembly, fuel cylinder plus a spare cylinder, transfiller, regulator system, battery charger 100V, extra filters, carrying case, maintenance and instruction manual, carrying straps for front mounting.
1653	Heath DETECTO-PAK® II complete unit as #1652 above with 220V battery charger (special order).
	Extra Accessories
3309	DETECTO-PAK® II Calibration Kit: Consists of demand regulator with gauge and tubing to fit Lecture Bottle 2.25 lbs (1.02 Kg)
4594	Battery Charger, 110V, 14 oz. (.88 Kg), 1 included in complete DETECTO-PAK® II unit #1652
3949	Battery Charger, 220V, 2.75 lbs. (1.25 Kg), 1 included in complete DETECTO-PAK® II unit #1653
1651	Mobile Accessory Kit: Consists of front sample assembly with tubing, high-volume pump with fittings, power cable, mounting brackets, carrying handle, and necessary hardware, 21.125 lbs (9.60 Kg)
2188	DETECTO-PAK® II Carrying Handle: Available as standard in mobile accessory kit or separately as an option, .5 lb (.22 Kg).
1555	Rain Cover: Transparent plastic cover provides protection for use in inclement weather, 2 oz (.125 Kg)

HEATH LOCATIONS

511 D Harbor Boulevard
W. Sacramento, CA 95691
916 371-2520

1809 Riley Road
New Castle, IN 47362
317 521-2068

98 Tosca Drive
Stoughton, MA 02072
617 341-0007

8909 H Street, Unit 3
Omaha, NE 68127
402 339-9070

Route 51, R.D. 4
Belle Vernon, PA 15012
412 929-2300

138 Space Park Drive
P.O. Box 110075
Nashville, TN 37222
615 833-1579

11710 Almeda Genoa Road
P.O. Box 75130
Houston, TX 77234
713 946-7664

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Heath Consultants Incorporated
100 Tosca Drive, P.O. Box CS-200
Stoughton, MA 02072-1591
617 344-1400 Telex 924485

Canada
Heath Consultants Limited
954 Leathorne Street, London Ontario N5Z 3M5
Canada 519 686-6446

FORM M045 0684 1M

HEATH CONSULTANTS

DETECTO-PAK II & MOBILE II UNITS

PRICE LIST

DESCRIPTION	HEATH PART NO.	PRICE
DETECTO-PAK II, Complete	1652	$3,750.00
DETECTO-PAK II CARRYING HANDLE	2188	128.05
OPTIONS FOR MOBILE CONFIGURATION:		
1. DETECTO-PAK II MOBILE KIT Consists of front sample assembly with tubing, high-volume pump with fittings, power cable, mounting brackets, carrying handle, etc.	1651	1,275.00
2. DETECTO-PAK II M BOOM SYSTEM Consists of bumper mounting bracket, boom, auxiliary vacuum reservoir, flag and bracket, control box and all necessary fittings and tubing.	200-358	1,450.00
3. DETECTO-PAK II RECORDER Consists of Model 400 Rustrak Chart Recorder with AC Inverter. Includes modification of DETECTO-PAK II for compatibility if purchased at the same time. NOTE: The DETECTO-PAK II must be modified to be compatible with the specific recorder that the customer may be using. If the modification is accomplished subsequent to purchase, a charge of $150 will be made.	3082	1,250.00
DETECTO-PAK II CALIBRATION KIT Consists of demand regulator and gauge and tubing to fit Lecture Bottle.	3309	250.00
Lecture Bottle w/100 ppm Methane	3071	68.00
LEAK PLOTTER BUILT TO CUSTOMER SPECIFICATIONS Price upon request - Price plus the cost of the vehicle.		

PRICES SUBJECT TO CHANGE WITHOUT NOTICE
ALL PRICES F.O.B. SHIPPING POINT

HEATH LOCATIONS

501 D Harbor Boulevard, P O Box 1267, W. Sacramento, CA 95691, 916 371-2520

1809 Riley Road, New Castle IN 47362, 317 521-2066

98 Tosca Drive, Stoughton MA 02072, 617 341-0007

8909 H Street, Unit 3, Omaha NE 68127, 402 339-9070

Route 51, R D 4, Belle Vernon PA 15012, 412 929-2300

138 Space Park Drive, P.O Box 110075, Nashville TN 37222, 615 833-1579

11710 Almeda Genoa Road, P O Box 75130, Houston TX 77234, 713 946-7664

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